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This report discusses the design of a micro-stereoscope and stereo-microscope as specified in contract [REDACTED]

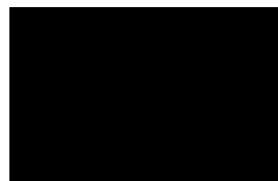
Three objectives have been met in the design of this instrument.

1. Ease of manufacturing to assure reasonable cost.
2. High quality performance.
3. Ease of operation.

In the course of meeting these design objectives, many problems, both optical and mechanical, have arisen. In order to understand the decisions made, some of the alternate solutions are discussed. It is felt that these decisions have resulted in very little compromise in the design objectives as originally stated.

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FIRST ORDER SYSTEM

Table one shows the object size, magnifications, and numerical apertures for each objective throughout the zoom range. This table applies to the micro-stereoscope only.

For the stereoscopic mode, the specification for the 1X objective ONLY 1X
will apply. IN 4210

The original working distance of 2", for the 4X objective, has been reduced to approximately .5", by request of the technical representative, to allow the lower power objectives to be reduced in working distance, so that a user can sit comfortably at the light table.

This change has resulted in a loss of power that can be achieved in the stereoscopic mode. However, we believe that we can supply two additional 20X wide field eyepieces, at no additional cost to the contract, which will result in a overall magnification of 80 power.

Some of the problems which we encountered by reducing the working distance, was that the lenses became too large to be placed together without mechanically striking each other, and that they had to be extremely fast in f number.

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There is a possibility that we would be able to use a 2X objective for the stereoscopic mode, which would have to be designed. However, there will be some degradation in the imaging quality X

The performance would be approximately 3 lines per power. In addition to the loss of power, the objectives that are used in the micro-stereoscope could not be interchanged or used in the stereoscopic mode.

The schematic shown on page 5 consists of the system starting from the objective.

1. Interchangeable 2X and 4X objectives, a fixed objective on each lens.
2. A fixed 1X objective for the stereoscopic mode.
3. ~~A two fixed 1X objective..~~ ?
4. A four component optically compensated zoom system.
5. A field lens.
6. A derotation prism system.
7. A relay lens.
8. A porro prism.
9. A camera lens. ← POLOCAID
10. 10 power and 20 power eyepieces.

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CONFIDENTIALMECHANICAL DESIGN

The mechanical mounting and overall dimensions shown on Page 7 reflects the improvements made on the microscope.

The size has been reduced considerably and the operating knobs are placed in positions which will allow the operator greater ease of operation than the original concept.

We have also incorporated an adjustable eyepiece which can be raised or lowered to suit the height of the operator.

There are two independent zoom systems in this microscope which can be operated independently or together. They can also be set for the various magnification within the 4:1 ratio individually and then operated together.

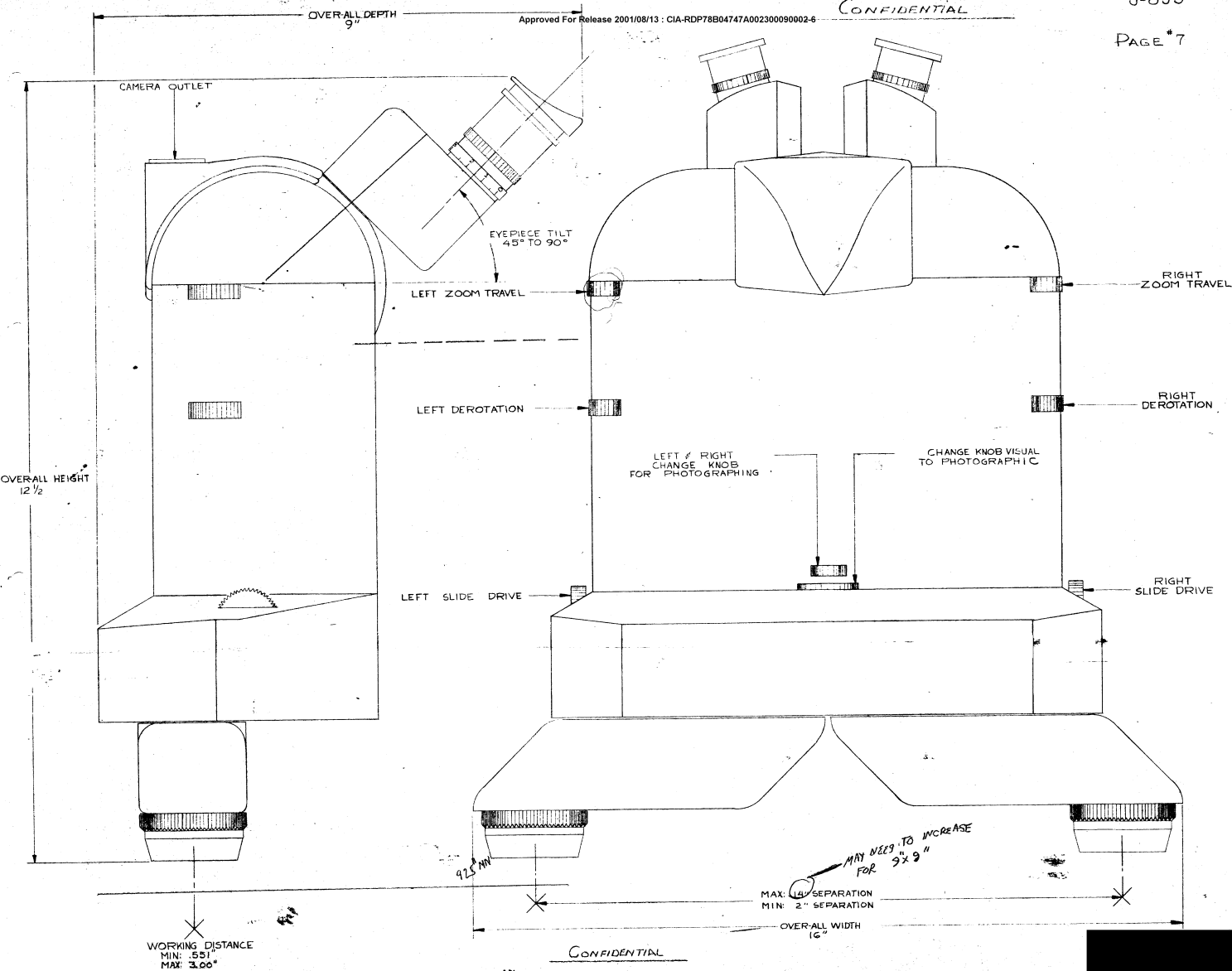
The dimensions shown on the outline drawing are what we believe we can maintain however, and departure from the dimensions shown will not be to any great magnitude.

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CONFIDENTIALA. OBJECTIVES

For the objectives three alternatives were available. First, three interchangeable objectives working at the infinite conjugate position could be used to form a nearly parfocal system. One mirror would be interchangeable with the objectives. Since the exit pupil position from the zoom lens is the same for any objective, the 4X objective becomes exceedingly large. This in turn, makes the mirrors large and the arms themselves quite large. The second solution would be to bring the collimated light from the zoom system to a focus, insert a field lens, and use interchangeable parfocal relay systems. A system such as this will be extremely small and precisely parfocal. The difficulty, however, arises from the fact that the relay objectives become very fast. The 4X objective, for instance, would be approximately $f/1.2$. It is extremely difficult to design diffraction limited $f/1.2$ objectives with long conjugate distances, and likewise extremely expensive to manufacture them to the required precision. ^{third} The interchangeable 2 X and 4 X objective system decided upon is not parfocal, varying in working distance from three inches to approximately $1/2$ inch. The main advantages are that no mirror must be interchangeable and the 1X objective is used to reduce the size of the 2X and 4X objectives. This, of course, will be rather easily manufactured. It also resembles the well known Lister microscope objective and lends itself to a known systematic design procedure.

CONFIDENTIALB. ZOOM SYSTEM

The zoom system was initially a strictly focal symmetrical type five component optically compensated relay. The basic first order properties of this zoom system have been maintained throughout the design. By replacing the dove prism with a new derotation prism system, the need for collimated light was eliminated and one component of the zoom system was removed, permitting the light to come to a focus. The image is transferred, by the means of a relay lens, to the eyepiece focal plane. Figure 2 shows a plot of the zoom magnification versus the drift in focus in numbers of focal ranges. Also shown in the plot is the out of focus condition in focal ranges as a function of magnification when the lens is two focal ranges out of focus at the high magnification position.

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C. Relay

In addition to the size reduction, the use of a relay lens provides two additional distinct advantages.

One, the exit pupil position presented to the eyepiece is strictly constant. It is a very desirable characteristic that the position of the eye in relation to the eyepiece is a constant for any given zoom magnification. The lack of fulfilling this condition is obvious when eyecups or headrests are used. Since an aperture stop is placed at the relay lens, the condition of constant exit pupil position is rigidly observed.

The second advantage of the intermediate relay is that the aperture stops can be an iris diaphragm, thus providing the means to stop down the system. This can be very desirable when viewing low spatial frequency, very low contrast objects.

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D. FIELD LENS

The field lens serves two purposes. First, it relays the exit pupil of the zoom system to the relay lens. Secondly, it is a hyperchromatic doublet correcting for a small, residual lateral color resulting from the zoom system. Since the crown and flint glass of this field lens are reversed from the normal positive doublet, the resulting field curvature is considerably less than the singlet field lens alone.

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E. CAMERA LENS

The camera lens picks up the intermediate image formed by the zoom lens and images it at approximately 5.25 magnification onto double frame 35mm film. The camera lens works at an object to image distance of approximately 360mm with a minimum object conjugate distance of approximately 120mm. The lens satisfying these requirements is a widely separated f/10 telephoto system, having a focal length of approximately 29mm.

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F. STEREO-MICROSCOPE

Since light on the object side of the zoom lens is collimated,

the same objective systems of the (micro-stereoscope) can be

used for the (stereo-microscope). *← IS TERMS ON P 3* Initially it was desirable to *NO!*

use a single objective for this mode of operation. The aperture

stop must be placed at the mirror which separates the two sides

of the stereo image. Since this zoom system is used for both

modes, this would dictate the aperture stop for the micro-stereo-

scope. This would result in an approximately 100% increase in

the size of the first zoom component, and consequently, increasing

the size of the mirror and the total instrument.

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CONFIDENTIALIMAGE QUALITY

The first step in determining the performance of the design is to ray trace the system and plot the conventional H Tan U or rim ray curves. Each of the curves plotted represents the deviation H from an ideal image point, as the ordinate plotted against the tangent of the angle that the ray makes with the optical axis in the image plane. In actual practice the abscissa is the difference of tangents of the ray and the chief ray (that ray which passes through the center of the entrance pupil of the lens). Thus $\Delta \tan U' = 0$ for the chief ray from any particular object point.

In addition to the tangential or meridional rays discussed above, the saggital or skew ray deviations are plotted as a function of their final angle made with the Y-Z plane. Because of the symmetry about the Y-Z plane, only one-half of the saggital fan is traced.

It can be shown that the slope of each curve through its respective origin is a direct measure of the focal position deviation from the paraxial image plane. These slopes thus represent field curvature, and the difference between saggital and the tangential slopes at a

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particular object point is a measure of astigmatism.

The symmetrical deviations of the curve from a straight line tangent to the curve at the origin are a measure of transverse spherical aberration. The assymetrical deviations from this same line are a measure of coma. Thus a perfect lens would be plotted as a family of straight lines with zero slope.

Since the ordinate is a direct measure of the blur circle in the par-axial image plane, a fairly good prediction of contrast and resolution can be made by study of these plots. Of greater value is that it is apparent which aberrations are affecting image quality. This enables the lens designer to determine what needs to be corrected, whether it can be corrected with the present basic optical configuration, and how to proceed.

Figure 3 shows the high contrast resolving power as predicted from the H Tan U plots. The Airy disk spot size criteria was used as a basis for determining diffraction effects.

Since the 1X objective balances some residual aberrations of the zoom system, and the 2X and 4X objectives are essentially aberration free, the image quality characteristics remain fairly constant for all three objectives. Therefore, the axial and field performance

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variations will be discussed as a function of zoom position.

First, the axial image quality at the 4X zoom position is essentially diffraction limited. The spherical aberration is well corrected with the only residual being slight spherochromatism and dominant secondary color. The result of the secondary color will be the usual purple imaging of black objects with a surrounding, yellowish-green haze. This condition is eliminated in apochromatic systems and greatly reduced in semi-apochromatic systems. At the 2X zoom position the axial spherical aberration is overcorrected. This overcorrection will result in a loss of contrast at high frequencies, but not enough of a loss to cause failure to meet the 5 lines per millimeter, per power resolving powers specifications. Again the secondary chromatic aberration is dominant and will cause purple imaging of black targets. At the 1X zoom position the spherical aberration is again corrected to a residual of nearly zero. The secondary chromatic aberration is far larger than the residual spherical aberration. There should be no problem imaging even the higher frequencies at high contrast.

At the 4X zoom position the edge of the field suffers from some sagittal spherical aberration, slight coma, and astigmatism. The

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astigmatism will cause some deterioration of the image quality. Going to the 2X zoom position, the astigmatism and coma completely disappear. The resulting image is as good at the edge of the field as it is on axis. At the 1X zoom position, the coma reappears along with slight astigmatism. Again, the image quality will deteriorate somewhat.

As previously explained, the lateral color is completely removed by the hyperchromatic field lens.

The camera objective is essentially diffraction limited over its entire field. Since the f/number is so large, there will be no variations of aberrations due to the other part of the system, and was thus evaluated with an unaberrated object. As can be seen by the aberration plot, the image on film will be as good as that in the eyepiece focal plane.

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CONFIDENTIALCONCLUSION

A conceptually sound system has been designed. It is extremely easy to manufacture and has reduced the operator effort to a minimum. The image quality is adequate, but could be improved.

[First, the secondary chromatic aberration can be reduced or eliminated by the use of the mineral fluorite. Since this material is not easy to obtain in good quality, nor is it easy to work with, the better compromise would be to investigate the use of the new phosphate crown and short flint glasses. Although this would not change the high contrast resolving power by a large amount, it is a desirable feature to have black objects image strictly black.] EXPANDED!

By additional work on the zoom lens, the variation of coma at the edge of the field as a function of zoom position could be reduced.

Although it is doubtful that the image quality at the edge of the field can be easily made diffraction limited throughout the zoom MTF
can be improved to a point of no noticeable deterioration. 2 MAN MTS. It would take approximately two additional man weeks to complete this work.

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CONFIDENTIALSUMMARY

This design that we are submitting could be improved, however we feel that it represents the original intent.

Although the stereoscopic made does not completely meet the magnification requirements, we feel that the 80X which can be achieved, may be suitable for the intended application.

WRONG
ASSUMPTION

The microstereoscope however, does meet all the requirements and has additional features which were added to the original concept and has improved the ease of the operation.

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Stereomicroscope

Contract [REDACTED]

Design Phase I

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